REFRIGERATION

INCLUDING AIR CONDITIONING AND COOLING AND HOUSEHOLD AUTOMATIC REFRIGERATING MACHINES

BY

JAMES A. MOYER, S.B., A.M., Mem. A.S.M.E., A.I.E.E.

State Director of University Extension in Massachusetts, formerly Junior Professor of Mechanical Engineering, University of Michigan, Professor in charge of the Mechanical Engineering Department, Pennsylvania State College, and Director of Pennsylvania Engineering Experiment Station

AND

RAYMOND U. FITTZ, S.B., Mem. A.S.R.E., S.P.E.E.

Assistant Professor of Mechanical Engineering, Tufts College

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ing effect to be 23.2° F. and the temperature differential 10° F., while the ice-melting rate was 0.813 pound per hour.

The use of ice baskets has been carefully studied.[1] These baskets permit a freer circulation of air, thus improving the box performance for a given ice consumption. The baskets are made of perforated metal or wire mesh. Broken or chunk ice may be used to fill the basket. The ice-melting rate was found from tests to be less than when the refrigerator was cooled without the baskets, and the cooling effect with the baskets was more uniform than without them.

The humidity of the outside air affects the humidity in the cabinet; that is, as the outside humidity rises, the box humidity in the cabinet likewise rises—but not so rapidly. This change in humidity affects the ice-melting effect, there being a greater ice consumption for increased humidity.

Refrigerants for Household Systems.—The refrigerants used in household refrigerating systems are ice, sulphur dioxide, ethyl chloride, methyl chloride, ammonia, carbon dioxide (not commonly used in America but used extensively in Europe), butane, isobutane, and dichlorodifluoromethane. These refrigerants can be classified into two groups: (1) non-inflammable and (2) inflammable. The non-inflammable refrigerants are carbon dioxide, sulphur dioxide, and dichlorodifluoromethane. The remainder of the group may burn when mixed in some proportions with air and must, therefore, be classified as inflammable. Not all of the above refrigerants are widely used in household machines. Those most commonly found are sulphur dioxide, methyl chloride, dichlorodifluoromethane, and ammonia. Isobutane and butane are used to some extent.

General Electric Company Refrigerating Unit.—The General Electric household refrigerator has been designed to occupy as little space as possible and to eliminate all exposed moving parts. It has been arranged to simplify the interchange of refrigerating units and to reduce to a minimum the possibility of gas leaks. An automatic control maintains constant refrigerating temperature. The refrigerant used in this machine is *sulphur dioxide*.

The General Electric unit resembles in many ways the Audiffren oscillating-cylinder refrigerating machine (p. 55), which has been successfully used for 25 years. There are five principal

[1] Belshaw, C. F., "Ice Baskets for Domestic Refrigerators," *Refrigerating Eng.*, Vol. 20, No. 5, pp. 291–294, November, 1930.

parts in the refrigerating unit: (1) compressor; (2) float valve; (3) evaporator; (4) automatic temperature control; (5) condenser. The parts are marked in Fig. 87.

Compressor.—The compressor of the General Electric unit is shown in Fig. 87. It has a single oscillating cylinder, and its piston is driven by an eccentric on the shaft of the electric motor.

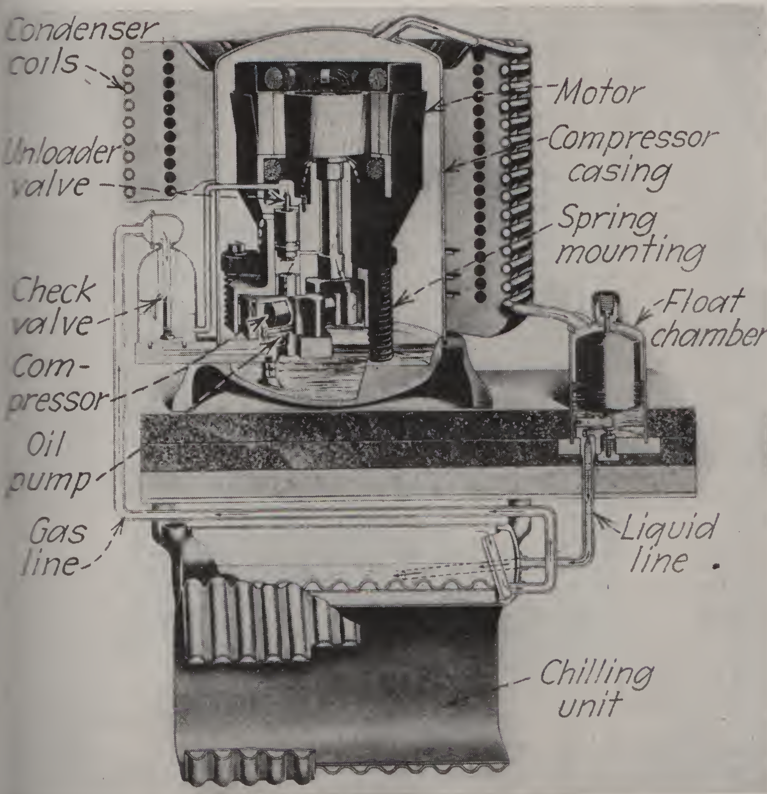


FIG. 87.—Diagram of General Electric icing unit.

The compressor is single-acting, being made with a 1-inch piston and a stroke of 0.7 inch. The compressor and motor are in a steel case which is provided with a steel base plate. The joint between the case and the base plate is made thoroughly leak-proof by means of a tongue-and-groove type of lead seal. Lubrication is by the forced-feed method that operates by means of a plunger type of oil pump which operates on the permanently sealed oil supply, somewhat as the piston of the compressor operates on the refrigerant. The oil pump is shown in the figure.

In order to reduce the starting torque of the compressor, an "unloader" valve is used. This valve is held up against its seat by oil pressure during the normal operation of the compressor but opens at low oil pressure when stopping, thereby allowing the pressure on the outside and the inside of the compressor cylinder to become equalized through a by-pass. At the time of stopping, a check valve closes and thus prevents the vapor at high pressure from leaking back into the evaporator through the suction line.

The entire mechanism is mounted within the steel case on three springs, so as to absorb motor noises and vibrations. This makes the refrigerating unit practically noiseless.

In order to reduce the viscosity of the oil and reduce the motor-starting torque, a little device called an "oil conditioner" is connected directly across the main electric line. This oil conditioner or heating element consists of a fine nichrome-steel wire embedded in porcelain and is made so that it is easily replaced through a hole located in the drop-forge steel base. The heater element draws about 10 or 12 watts at 110 volts. This input is not, however, an additional load as the over-all actual input to the unit is increased only 5 watts. The oil conditioner also serves to drive off any sulphur dioxide held by the oil thus eliminating the sulphur-dioxide condensate from accumulating in the base.

Float Chamber.—The float chamber is located on the top of the refrigerator cabinet to one side of the compressor case and condenser. Its purpose is to separate the high- from the low-pressure sides of the system, and to accumulate the liquid refrigerant. When there is a sufficient quantity of liquid in the float chamber, the float valve[1] lifts and allows the liquid refrigerant to flow into the chilling unit or evaporator.

Evaporator or Chilling Unit.—The evaporating device is located on the inside of the cover of the cabinet and is an integral part of the unit. It is made of two steel sheets, one of which is corrugated. These sheets are folded into shape with the upper part of the inner and outer sheets forming a cylinder-shaped header. The sheets are brazed and welded together electrically. This construction produces in effect a series of parallel tubes extending around the outer surface of the chilling unit. These tubes open into the refrigerant reservoir. In the central recess of the evaporator are two or more trays. These trays may be used to make ice cubes or frozen desserts.

[1] The adjustment of the float valve is made at the factory.

Control of Temperature.—The temperature-regulating device is located in a central box placed on the top of the refrigerator cabinet to the left of the compressor, as shown in Fig. 88. This control performs three functions: (1) Starts and stops the electric motor as the temperature changes in the evaporator; (2) cuts off the current whenever there is an overload, thus preventing damage to the motor; (3) varies the temperature of the cabinet as desired.

The temperature-control mechanism is shown in Fig. 89 and consists of a "sylphon bellows" to which a copper tube is attached,

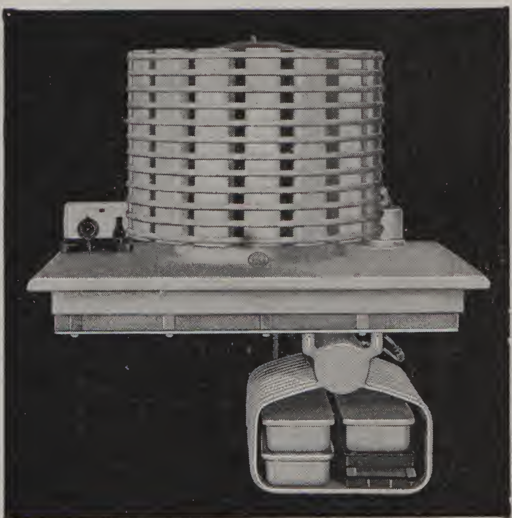


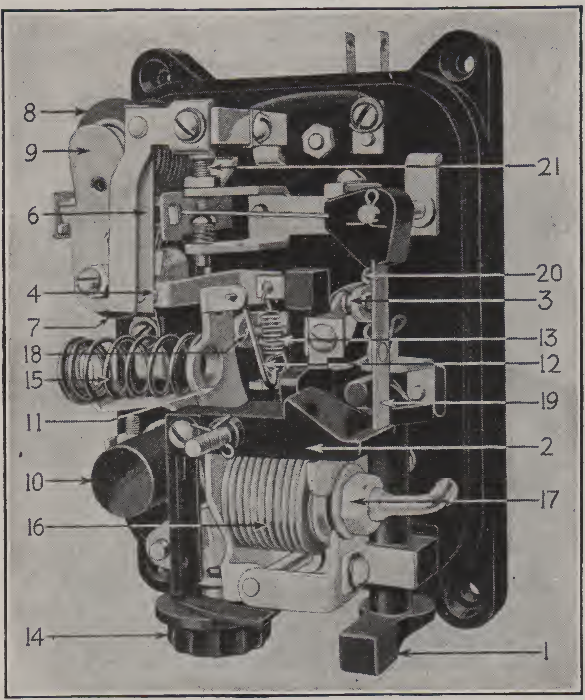
Fig. 88.—General Electric icing unit showing parts in place.

the other end of which is in contact with the evaporator. This copper tube is filled with sulphur dioxide and is not in any way connected to the sulphur dioxide in the main unit. As the temperature in the cabinet rises, the pressure of the sulphur dioxide in the tube rises and likewise the pressure in the sylphon bellows, forcing the bellows to expand and close the switch which starts the motor. On the other hand, a decrease in temperature in the evaporator causes a reduction in pressure in the sylphon bellows which causes the switch to open, cutting off the electric current and stopping the motor.

A dial with a pointer is provided so as to decrease or increase the tension of the temperature-control mechanism to be set for a

range of 20° F. In order to prevent damage from overload, an overload heater element trips the overload cutout element which opens the electric circuit.

Electric Circuit.—The electric circuit for the General Electric icing unit is shown in Fig. 90. It should be noted that in the



1. Main switch
2. Latch and indicating arm
3. Main contacts
4. Starting contacts
6. Starting contact spring
7. Starting relay series coil
8. Starting relay shunt coil
9. Starting relay armature
10. Starting resistor
11. Lever for automatic control
12. Bridle
13. Bridle spring for contact arm
14. Temperature adjusting knob
15. Temperature adjustment spring
16. Metallic bellows
17. Clamp nut on bellows
18. Temperature-range adjusting screw
19. Overload cutout
20. Overload heater
21. Overload adjusting screw

Fig. 89.—Temperature-control mechanism.

design of this unit there must not be any electrical contacts within the hermetically sealed casing. The induction motor if it is to run on a single-phase 60-cycle 110-volt circuit must have a special wiring circuit other than that commonly used with split-phase induction motors for starting.

This induction motor is provided with two windings, namely, the starting and running windings. The starting winding is to

be cut out of the circuit after the motor is up to speed. This necessitates the use of a series starting coil and a shunt starting coil, the starting shunt coil being cut out of the circuit by the series coil opening the starting contacts when the motor has come up to its normal speed. The main contacts are closed and opened

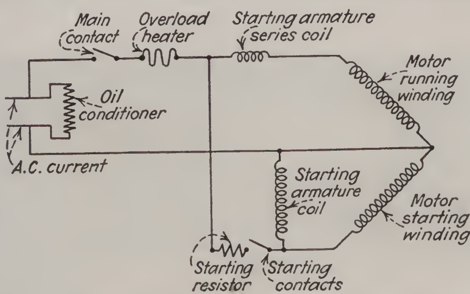


FIG. 90.—Wiring diagram of General Electric refrigerator.

by the pressure of the sulphur dioxide in the sylphon bellows and copper tube.

The starting operation is as follows: The sylphon bellows closes the main contacts, and the electric current flows into the running winding and starting winding as the starting contacts are closed. The starting resistance being located in the starting circuit causes a sufficient phase displacement between the two currents in the two windings to start the motor against its starting torque. As the current reaches a maximum in the running winding, the series coil opens the starting contacts, cutting out the starting winding. When the main contacts open the armature of the starting coil returns to its starting position, closing the starting winding-circuit contacts, so that the circuit is in its normal starting condition.

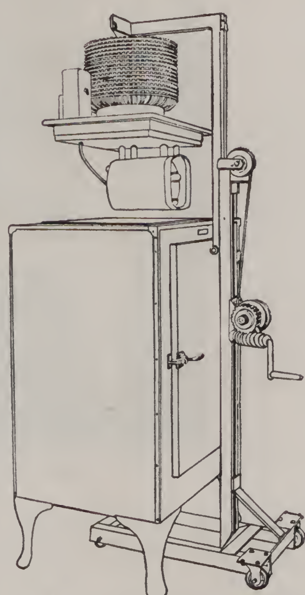


FIG. 91.—Portable crane for removing General Electric icing unit.

In some districts of our cities direct current is used and because of the fact that the General Electric icing unit has an induction motor it is then necessary to convert the direct current into alternating current.

This is accomplished by the use of a small rotary converter which is designed to operate on a 110-volt direct-current line.

The installation of this refrigerating unit consists only of placing it in position at the top of the cabinet; and since there are no pipe connections to be made, it is easily installed in an apartment or a house. Figure 91 shows a crane for conveniently

FIG. 92.—General Electric refrigerating unit.

removing and replacing this unit in a refrigerator. A typical household refrigerating unit is shown in Fig. 92.

At the factory, the standard method of testing this machine is to submerge the evaporator in a brine bath held at a temperature of 20° F. while the condenser for the refrigerant is at room temperature. With these conditions, one of the small units has a refrigerating capacity of 320 B.t.u. per hour, when the electric-

power input is 150 watts and the room temperature is 100° F. The condenser gage pressure is 110 pounds per square inch while the suction pressure corresponds to a vacuum of 4 inches of mercury.

When this refrigerating unit is installed in a room having a temperature of 100° F., it will run about 70 per cent of the time when the doors of the refrigerator are kept closed. Under this condition, the average suction pressure is slightly lower than during the brine test method above, and the refrigerating capacity of the machine will be slightly reduced.

The following table gives the capacities of the General Electric refrigerating units operated in a room held at 80° F. and at a chilling unit temperature of 20° F.

Model	Capacity, B.t.u. per hour	Size of motor, horsepower	Speed, revolutions per minute
DR-1	300	$\frac{1}{10}$	1,740
D-2	420	$\frac{1}{8}$	1,740
D-35	670	$\frac{1}{6}$	1,740
DR-4	1,400	$\frac{1}{3}$	1,740
D-50	2,100	$\frac{1}{2}$	1,740

Frigidaire Compression Refrigerating System.—The Frigidaire system made by the Frigidaire Corporation (General Motors Corporation) is of the compression type and operates according to the following cycle: The heat is absorbed from the refrigerating cabinet by the evaporating refrigerant, which is *dichlorodifluoromethane*, which hereafter will be known as "F-12," and is carried away by the cooling water or air, whichever cooling medium is used for the condenser. The compressor, driven by an electric motor, serves to keep the refrigerant circulating through the system and increases the pressure of the refrigerant so that it may be readily liquefied in the condenser. The F-12 which has been condensed flows into the liquid receiver from which, by the difference in pressure, it is forced through a tube into the cooling coil of the evaporator. The flow of the liquid F-12 into the cooling coils is controlled by an expansion valve of the float type, as shown in Fig. 93. This valve serves two purposes: (1) to maintain a pressure on the liquid line so as to keep the F-12 in the liquid state at "room" temperatures, and (2) to allow the liquid F-12 to flow into the cooling coil of the evaporator rapidly enough to replenish the refrigerant which has been evaporated

Enclosed Compression Unit.—An unusual type of refrigerating machine in which the compressor, condenser, brine cooler, and pipe system are in a single unit is shown in Fig. 36. The Audiffren-Singren refrigerating system, made for the H. W. Johns-Manville Company, is contained in two nearly spherical chambers *A* and *V*. There is a hollow shaft *S*, supporting a bowl-shaped casting *B* which is kept from turning by a heavy weight *W*. This casting carries the trunnions *T*, *T* of a cylinder *C*, the piston *P* of which is connected to a rod attached to the strap of an eccentric *D* on the shaft *S*. The shaft *S* is driven by means of a belt on the pulley *Q*. The circular chamber *A* and the oval

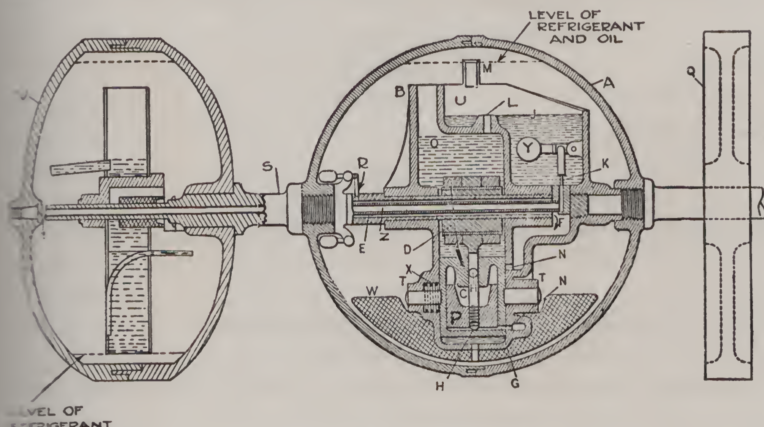


Fig. 36.—Audiffren-Singren refrigerating apparatus.

chamber *V* are revolved by the shaft *S*. When the shaft rotates the chamber *A*, the cylinder *C*, which is a part of the large chamber *B*, remains nearly stationary, *oscillating* only a little under the influence of the heavy weight *W*, which causes it to hang down. The piston *P* in the cylinder *C* is drawn in and out of the cylinder by the eccentric *D*. The cylinder *C* oscillates between the "faces" of the suspended bowl-shaped casting *B* on the trunnions *T*, *T*. The right-hand face of the cylinder *C* is pressed by the spring *X* against the face of the lower part of the casting *B* which contains ports or holes marked *N*.

In this way, ports or holes in the two ends of the cylinder *C* are connected to the two suction ports *N*, *N* in the lower part of the casting *B* at the proper times in somewhat the same way that the distribution of steam is brought about in the cylinder of a reciprocating engine. Thus, the vapor of the refrigerant (sulphur

dioxide) is admitted to the cylinder *C* at *F*, from the annular space *E* between the two hollow shafts. When the port or hole at *G* in the cylinder *C* and in the "face" at *N* come opposite, the vapor of the refrigerant is admitted into the cylinder and is compressed. When the proper pressure is reached, the cylinder discharge valves at *H* open and discharge the vapor into the casing *A*. Now, the casing *A* *revolves* (partly immersed) in a tank containing water for cooling, which condenses the refrigerant and this liquid together with the oil supplied for lubrication collects by centrifugal force at the outer part of the revolving casing *A*, where some of it is caught up by a scoop *M* and is collected in the reservoir *J*. After the lubricating oil is removed, some of the liquid refrigerant passes through an expansion valve *K* which is regulated by a suitable float *Y*.

The oil floats in the reservoir *J* and overflows through the hole *L* into the chamber *O*, in the lower part of which the cylinder *C* oscillates, so that the eccentric *D* and the piston *P* are flooded with oil. The whole interior is under pressure, so that there is no leakage of refrigerant from the chambers. There is a tendency for the oil to enter around the piston rod and between the valve faces; but the spring *X* holds the lower part of the casting *B* against the sliding face containing the port or hole *N*. The liquid refrigerant which is at low pressure after passing the throttling expansion valve *K* passes along the inside of the inner shaft extending between the two chambers *A* and *V* and finally settles, by centrifugal force, at the circumference of the oval-shaped chamber *V*. In the low-pressure chamber *V* (evaporator), the liquid refrigerant is vaporized as it removes heat from brine in a tank in which it revolves.

The vapor of the refrigerant returns from the chamber *V* to the chamber *A* through a space (not shown) formed between the two hollow shafts which connect the chambers *V* and *A* and then passes again into the compressor through the annular space *E* and the opening *F*. The complete system is contained within a tight set of nearly spherical chambers and shafts, so that there are no moving joints to be kept tight, and, consequently, there is no danger of leakage. An extension on the right-hand chamber serves as one journal for the system, and the hollow shaft at *S* serves as the other. There is little weight on the journals, as the buoyancy due to the two chambers *A* and *V* being immersed supports much of the weight. The pressure of the vapor of the

refrigerant in the chamber A, in addition to the spring pressure, tends to keep tight the sliding joint between the oscillating piston P and the "face" of its cylinder. Should the cooling water be shut off and the temperature rise, the high pressure developed would finally be sufficient to cause the weight W to rotate and so prevent a further rise in pressure. The small valve at R is held down, when the apparatus is in operation, by centrifugal force of the ball weights, as shown, but upon stopping the machine, this valve is opened by the weight of the balls, thus equalizing the pressure.

The cooling water in a tank below the chamber A *condenses* the vapor of the refrigerant while the *evaporation* of the liquid refrigerant in the chamber V cools the brine in another tank. When the brine in this tank is cooled to approximately the temperature of the vapor of the refrigerant, there will be no further evaporation of the liquid refrigerant, no vapor will be sent back to the compressor in the chamber A, and, consequently, no vapor will be liquefied in the chamber A. After a short time of operation of the apparatus, the level of the liquid in J will close the float valve K, and no more liquid refrigerant can pass over to the evaporator in the chamber V.

Compound Ammonia Compression System.—It has usually been considered good engineering practice to install an ammonia absorption refrigerating system when a low temperature was to be maintained in the cold-storage rooms or when the suction- or inlet-gage pressure was less than 10 pounds per square inch. There are, of course, many single-cylinder ammonia *compression* systems which are operating with a lower suction pressure than this value. It is generally admitted, however, that the single-cylinder ammonia compressor does not give satisfactorily economical operation with such low suction pressure, and the ultimate plan of operation for best economy is either to install an absorption refrigerating system or use a compression system which is equipped with a compound (two-stage) compressor. The compound ammonia compression system is, of course, more complicated than the system requiring only a single-cylinder compressor. The compound compression system requires, in addition to the usual equipment of the ordinary compression system, the following apparatus: (1) high-pressure compressor cylinder; (2) low-pressure compressor cylinder; (3) low-pressure discharge vapor cooler; and (4) intermediate receiver.